

²Infrasound Laboratory, University of Hawaii, Manoa, 73-4460 Queen Kaahumanu Hwy., no. 119, Kailua-Kona, HI 96740-2638, United States

Vulcanian and Plinian volcanic eruptions may be thought of as turbulent, large-scale free-shear jet flows that transition with altitude into buoyancy-driven volcanic plumes. In early attempts to link acoustic radiation with fluid mechanics at volcanoes, it was proposed that turbulence within volcanic jets may generate quadrupole radiation according to Lighthill's acoustic analogy. However, measurement of the sound radiation pattern from large volcanic eruptions has proven challenging. In addition, it is now known that quadrupole radiation from fine-scale turbulence is just one component of jet noise, and that noise from large-scale turbulence structures, screech, and broadband shock can be important depending on the jet operating conditions. Recently, arrays of broadband infrasonic sensors located tens of kilometers from Mount St. Helens, USA, and Tungurahua, Ecuador, have recorded several high-amplitude signals associated with Vulcanian and Plinian eruptive activity. We present evidence that these infrasonic signals represent a low frequency form of jet noise. Our data indicate that broadband infrasonic measurements of powerful volcanic eruptions may provide a quantitative link to eruption jet dynamics and ash column heights, and aid substantially in the remote sensing of volcanic hazard.

V34A-04 1645h

Experimental Simulation of Volcanic Steam Blasts and Jets at High Pressure Ratios

Joanna M. Austin¹ (jmaustin@uiuc.edu)

Mara S. Morgenstern² (mmorgens@uiuc.edu)

Susan W. Kieffer² (skieffer@uiuc.edu)

¹University of Illinois, Department of Aeronautics, Urbana, IL 61801, United States

²University of Illinois, Department of Geology, Urbana, IL 61801, United States

End-member compositions of plumes from volcanic eruptions range from nearly pure steam to heavily particle-laden gas flows. In all cases, if the plumes erupt from a high-pressure reservoir, they are initially supersonic jets that may have complex internal flow structures not easily documented in the field. In the laboratory, some properties of volcanic jets can be investigated with particle-laden flows, but other properties can only be investigated in optically transparent flows. We examine the relation of unsteady jet structure to reservoir conditions for optically transparent flows. We have developed an experimental shock tube facility capable of achieving pressure ratios up to ~150 with reservoirs of different shapes. Time-resolved schlieren visualization is combined with pitot pressure measurements to interrogate the structure of the underexpanded jet flow. We have done preliminary experiments at a pressure ratio of 40 with air, with two reservoirs that are 12.6 and 20 cm in length. These initially produce well-defined supersonic jets that have properties (shape of the underexpanded jet; barrel shocks; Mach disk shocks) which we have benchmarked against other experiments and simulations. Estimated durations of the supersonic portions of the flow from pressure decay calculations are ~45 and ~75 ms, respectively. On these time-scales, the experimental jets collapse: the plume boundary and internal barrel shocks tighten and the Mach disk shock moves toward the vent, until subsonic conditions occur.

V34A-05 1700h INVITED

Air entrainment and the dynamics of volcanic jets and plumes

Larry G Mastin¹ (360-993-8925; lgmastin@usgs.gov)

Stephen Solovitz² (360-546-9253; stevesol@vancouver.wsu.edu)

¹U.S. Geological Survey, 1300 SE Cardinal Court, Vancouver, WA 98683, United States

²Washington State University Vancouver, Department of Mechanical Engineering 14204 NE Salmon Creek Avenue, Vancouver, WA 98686, United States

During a typical pyroclastic eruption, gas and pyroclasts exit a volcanic vent at speeds of tens to hundreds of meters per second. At the vent the mixture is negatively buoyant, and rises as a plinian column only if it ingests and heats sufficient air to attain positive buoyancy. As erosion increases vent radius r^2 during an eruption, eruptive mass flux increases with r^2 , but the mass of air entrained increases only with r^1 . Hence the column ingests progressively less air relative to its mass and eventually, at some threshold mass flux m , collapses. The threshold mass flux m depends strongly on the air entrainment coefficient c , i.e. the velocity of intruding air normalized to the upward jet velocity.

The value of c is not well characterized in the near-vent region, and likely varies with vent geometry, overpressure, and jet density among other factors. Theoretical scaling relations suggest that a two-fold variation in c (e.g. 0.05-0.10) results in a four-fold variation in m . Numerical models of overpressured jets show that near-vent entrainment may be inhibited by shock waves, promoting partial or oscillatory column collapse within an otherwise steady plinian column. Here we present the first results of laboratory experiments using particle image velocimetry to quantify near-vent air entrainment. In these experiments, we use a jet of compressed air seeded with 3 μ m TiO₂ tracer particles, exiting a vertically-directed pipe 1.27 cm in inside diameter and 18 cm long, with upstream pressures of 0 to 21 kPa, producing a pressure-balanced jet at the exit with velocities up to about 180 m s⁻¹. The ambient air was seeded with tracer oil droplets a few micrometers in diameter from a fog machine. The seeded jet was illuminated by a 0.5 mm-thick Nd:YAG laser sheet that extended 5 cm above and horizontally from the vent. Particles illuminated by this sheet were photographed by pairs of images separated in time by 10 to 200 μ s, from which we were able to extract flow vectors. In our experiments, the jet starts impulsively by developing a mushroom-shaped head, whose base is surrounded by inward- and upward-oriented vectors that indicate concentrated air engulfment. For steady flow, vectors in ambient air near the jet base are directed horizontally inward; but as the horizontal distance from the jet margin increases from 0.5 to 5 jet diameters, vector orientation becomes steeply upward. The large vertical component of air velocity suggests that the presence of a crater or other topography may affect air entrainment. Also, upward air movement may accentuate the entrainment into the jet of fine debris elutriated from pyroclastic flows on the volcano's flanks.

V34A-06 1715h INVITED

Vulcanian eruptions: experimental insights into leading shock waves, initial acceleration, and flow evolution

Amanda Bachtell Clarke¹ (amanda.clarke@asu.edu)

Kirsten N Chojnicki¹ (kchojnic@asu.edu)

Jeremy C Phillips² (j.c.phillips@bristol.ac.uk)

¹School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-1404, United States

²Department of Earth Sciences, University of Bristol, Bristol BS8 1RJ, United Kingdom

Vulcanian eruptions are frequent, small-scale, short-lived explosions that occur as a result of rapid decompression of a volcanic conduit. Results of two relevant experimental studies are presented here. The first examines the initial burst phase and leading shock waves via 1-D shock-tube experiments in which mixtures of air and spherical particles are rapidly decompressed into a low-pressure environment via diaphragm rupture. Maximum gas-particle mixture velocities decrease with increasing particle diameter for a given initial pressure ratio across the diaphragm. Experiments with particles produce weaker and more slowly propagating shocks relative to experiments with air alone. Comparison of experimental data to theoretical and computational solutions leads to two key results: 1) the effective interphase drag coefficient during high-acceleration stages of an eruption is less than values previously used in multiphase models of explosive eruptions; therefore a new formulation is prescribed; and 2) leading shock waves are formed by the gas phase alone, not the solid-gas mixture, with shock wave characteristics reflecting losses due to drag between air and particles; therefore shock wave calculations should consider these losses rather than treat the system as a perfectly-coupled pseudogas. The second set of experiments examines the subsequent propagation of the pyroclastic jet or plume by injecting discrete pulses of pressurized (negatively or positively) buoyant fluids into fresh water. Dimensional analysis, based on two source parameters, total injected momentum and total injected buoyancy, identifies a universal scaling relationship for the initial propagation of short-duration impulsive flows; the non-dimensional, time-varying velocity varies as the square root of the time-varying, non-dimensional ratio of source parameters. The relationship successfully describes the experimental trends over a wide range of initial conditions as well as flow propagation of several well-documented Vulcanian eruptions. The formulation expands the range of available theoretical relationships appropriate for Vulcanian explosions, which have typically been treated as steady plumes or discrete thermals (buoyancy only). The utility of both experimentally-determined relationships is demonstrated by estimating vent pressures and time-varying vent mass flux and total mass erupted for several sets of field data, with results comparing favorably to independent estimates. Studies such as these can be used to understand basic volcanic processes, to interpret field data, and to validate numerical models of volcanic eruptions.

V34A-07 1730h

Simulating the Initial Dynamics of the 18 May 1980 Mount St. Helens Blast

Tommaso Esposti Ongaro¹ (+39-0508311937; ongaro@pi.ingv.it)

Christina Widiwijayanti² (cwidiwij@geosc.psu.edu)

Barry Voight² (voight@ems.psu.edu)

Amanda B. Clarke³ (Amanda.Clarke@asu.edu)

Augusto Neri¹ (neri@pi.ingv.it)

¹Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Via della Faggiola 32, Pisa 56126, Italy

²Penn State University, Department of Geosciences, University Park, PA 16802, United States

³Arizona State University, School of Earth and Space Exploration, Tempe, AZ 85287-1404, United States

The initial stage of the 18 May 1980 blast at Mount St. Helens (MSH) has been simulated numerically by the 2D/3D multiphase multiparticle flow model PDAC (Neri et al., J. Geophys. Res. 108 (B4), 2003; Esposti Ongaro et al., Parallel Computing 33, 2007), to provide further insight into the fluid dynamics of this phenomenon. Initial source conditions, including the gas content, the total mass of juvenile and entrained rocks, the temperature, grain size distribution and pre-eruption pressure distribution in the lava dome have been parameterized accordingly to field evidence, available geological constraints and simple theoretical models. Simulation results suggest that the MSH blast can be characterized as an expansion phase (burst), lasting about ten seconds, followed by collapse and pyroclastic density current (PDC) phases. In the burst phase the pressure forces dominate and the flow can locally reach supersonic velocities and generate pressure waves that can be tracked by the numerical model. In the collapse and PDC phases the flow is dominantly gravity-driven and the dynamics are strongly controlled by the source geometry, vertical stratification within the flow and by the 3D topography. The simulations suggest that the severe damage observed at MSH can be explained by high dynamic pressures in gravity currents, and the rapid decrease of dynamic pressure from proximal to distal areas (and related parameters of PDC velocity and density) was largely related to rugged topography beyond the North Fork Toutle River valley. Although the source models investigated thus far represent a simplification of the actual geometry and complex sequence of initial events, we show that the explosion mechanisms are significantly robust over a wide range of initial conditions. Simulation results for MSH are also consistent with those obtained in a previous application of a similar model to the 1997 Boxing Day blast pulses at Soufriere Hills volcano (Montserrat, West Indies) (Esposti Ongaro et al., J. Geophys. Res. 113 (B03211), 2008), which were at least ten times smaller, thus suggesting that the simulated mechanisms are largely independent of eruption scale.

V34A-08 1745h INVITED

Effects of complex vent geometry on volcanic jet decompression

Darcy E Ogden (dogden@es.ucsc.edu)

Department of Geophysics Stanford University, 397 Panama Mall Mitchell Building 360, Stanford, CA 94305-2215, United States

Volcanic jets consist of a high-pressured reservoir decompressing through a conduit, ultimately expanding into the atmosphere. Close to the surface, the conduit can flare rapidly, forming a volcanic vent. Here I present time-dependent multiphase and pseudogas numerical simulations of volcanic jet decompression through different 2 and 3D vent geometries. Depending on vent shape alone, the expansion of the same high-pressure reservoir can result in subsonic jets at atmospheric pressure or supersonic jets with pressures that are greater than, less than, or equal to atmospheric pressure. These different vent exit conditions then control the fluid dynamics of the eruption including jet structure and velocity, column stability and the nature of the acoustic signal produced. The numerical simulations presented here will be used to predict likely vent geometries for different eruption scenarios, and preliminary comparison of simulation data to acoustic observations will be presented.